

ASSEMBLY OF IMAGING ARRAYS
FOR LARGE FORMAT DOCUMENTS

Field of the Invention

5 The present invention pertains to large arrays of imaging devices. A preferred implementation of the invention is applied to very long linear arrays of either photosensors or image creating structures. Such long linear arrays can be used to record or create large format documents such as posters or engineering drawings.

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Background of the Invention

Image sensors for scanning document images typically have a row or linear array of photosensors together with suitable supporting circuitry integrated onto a silicon chip. Analogous devices for creating images in response to digital image data, such as LED print bars in Xerographic printers, or ink jet printheads, include a linear array of image creating structures similarly integrated onto a semiconductor silicon chip. In either case, because of the difficulty in economically designing and fabricating an array comparable in length to the width of an image to be created or recorded, various additional structures are typically used. In the scanning context, an optical reduction structure may be used to optically reduce the original image so that light from the image is reduced to the array of a single chip. In creating an image, a single chip can be reciprocated across the document. For example, in ink jet printing, a carriage may reciprocate a single chip for numerous swaths across an image substrate to create the image. However, certain advantages can be

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achieved if an array can be structured to record or create a very large image directly, using a full-width array.

In the scanning context, a full-width scanning device is described in U.S. Patent No. 5,272,113. In the device described in that reference, several individual silicon chips, each with a small linear array of imaging structures thereon, are placed on a substrate in an end-to-end relationship to form what is effectively a single page width array of photosensors. A challenge of creating such a single full-width array is spacing the chips relative to one another so that the photosensors of the array are evenly spaced with a minimum of anomalies, particularly between the last photosensor of one chip and the first photosensor of the adjacent chip. Complicating the spacing challenge is that the coefficient of thermal expansion of the chips themselves may differ from the coefficient of thermal expansion of the printed wiring board or other structure upon which the chips are mounted.

Summary of the Invention

The apparatus of the present invention is an imaging apparatus that includes first and second substrates, a first imaging device mounted on the first substrate, and a second imaging device mounted on the second substrate. A glass tie bar has a first portion attached to the first substrate, and a second portion attached to the second substrate. In particular implementations, the first and second portions of the tie bar are attached to the first and second substrates by an adhesive cured by a mechanism other than heat, such as by a light curable adhesive.

The method of the present invention is a method of forming an imaging apparatus. The method includes forming a first imaging subarray that includes a first printed wiring board, and a plurality of first semiconductor imaging chips, including a first end chip. The first printed wiring board has a joining end, and a portion of the first end chip projects beyond the joining end

of the first printed wiring board. The method further includes forming a second imaging subarray that includes a second printed wiring board, and a plurality of second semiconductor imaging chips, including a second end chip. The second printed wiring board has a joining end, and a portion of the second end chip projects beyond the joining end of the second printed wiring board. The method further includes bringing the first imaging subarray into proximity with the second imaging subarray so that the first end chip is immediately adjacent the second end chip. A light curable adhesive is applied to the first board and to the second board. A glass tie bar is placed so that a first portion of the tie bar contacts the light curable adhesive on the first board, and a second portion of the tie bar contacts the light curable adhesive on the second board. Light is directed onto the light curable adhesive to cure the light curable adhesive.

Brief Description of the Drawings

Figure 1 is a plan view showing an assembly of imaging arrays, according to one aspect of the present invention.

Figure 2 is an enlarged plan view of a portion of the assembly shown in Figure 1, illustrating the connection between adjacent arrays.

Figure 3 is a cross sectional view taken along line 3-3 of Figure 2.

Figure 4 is a cross sectional view taken along line 4-4 of Figure 2.

Figure 5 is an enlarged view of the edge of one of the imaging chips incorporated in the assembly shown in Figure 4.

Figure 6 is a cross sectional view taken along line 6-6 of Figure 1.

Detailed Description of a Preferred Embodiment

Referring first to Figure 1, an extended length linear array 10 of imaging chips, in accordance with an aspect of the present invention is formed of a plurality of imaging subarrays 12. Each imaging subarray 12 contains a plurality of silicon semiconductor imaging chips 14 mounted on a supporting substrate, such as a printed wiring board 16. As seen in Figure 2, each semiconductor imaging chip 14 includes thereon an array of individual imaging structures 18, such as photosensors, or LED emitters, or portions of ink jet ejectors. In the particular configuration illustrated, the individual imaging structures 18 on a single chip are arranged in a linear fashion. In addition, adjacent chips are arranged so that the imaging structures of the adjacent chips are aligned with one another. Thus, the imaging structures of the chips of a single imaging subarray 12 are arranged in a linear fashion. Each printed wiring board 16 on which an imaging subarray is formed may further include thereon printed circuitry 20 to enable external circuitry to access the circuitry on each semiconductor chip 14. The printed wiring boards 16 may be formed of conventional printed wiring board material, or of low thermal expansion Ceracom™ printed wiring board material, which has a coefficient of thermal expansion of 5.9 parts per million per degree Celsius (5.9 ppm/°C). Ceracom™ printed wiring board material is available from Ibiden Co., Ltd. of Ogaki, Gifu, Japan.

Referring now to Figures 2 and 4, a portion of the semiconductor chip 14 at the end of each printed wiring board 16 overhangs or projects beyond the end of the printed wiring board substrate. This overhang allows the imaging chips of adjacent subarrays to be placed proximate one another so that the end chip of one subarray 12A is immediately adjacent the end chip

of the next subarray 12B. This arrangement allows the close spacing of the individual image elements, without the adjacent printed wiring boards 16 contacting one another. The exact amount of projection or overhang will vary by application, but should be sufficient to ensure that, within the manufacturing tolerances of the assembly system, adjacent imaging chips from adjacent subarrays may be placed in close proximity without the underlying printed wiring boards contacting one another. Thus, the nominal specifications should be such that, accounting for inherent variations in manufacturing repeatability, the end chip of each imaging subarray projects beyond the end of the printed wiring board. For example, a chip projection of 0.015 inch (0.038 mm) may be sufficient.

The end of each printed wiring board 16 that is adjacent another printed wiring board may be referred to as the joining edge. The end chip of the first subarray 12A that overhangs the joining edge of the first printed wiring board 16A is very closely spaced from the end chip of the second subarray 12B that overhangs the joining edge of the second printed wiring board 16B. Ideally, the chips are spaced so that the spacing between the end imaging element 18 of the first end chip and the end imaging element of the second end chip is the same as the spacing between the elements on each chip. For example, the chips may be spaced approximately 1-2 microns (0.00004-0.00008 inch) from one another. In some circumstances the chips 14 of the adjacent subarrays 12 may even abut one another. If each chip projects approximately 0.015 inch (0.38 mm), then the gap between the adjacent joining of the printed wiring board of the first subassembly and the printed wiring board of the second subassembly will be approximately 0.030 inch (0.76 mm).

The adjacent imaging subarrays 12 are joined together by tie bars 26. The tie bars 26 are formed of low expansion borosilicate glass having a coefficient of thermal expansion of approximately 3.25 ppm/°C. Exemplary glass of this type is Corning Pyrex 7740 or Schott Tampax 8330.

5 A feature of this type of glass is that its coefficient of thermal expansion closely approximates the coefficient of thermal expansion of the semiconductor imaging chips 14. In certain circumstances, ordinary glass may be used to form the tie bars 26.

Each tie bar 26 is approximately 0.125 inch (3 mm) thick, has a

10 length of approximately 0.787 inch (20 mm), and a width of 0.228 inch (5.8 mm). One side of each tie bar glass block is frosted, either chemically or mechanically. The frosted side is attached to the printed wiring board. Each tie bar 26 attaches two imaging subarrays 12 to one another. Preferably, the tie bars are secured to the printed wiring board substrates 16 upon which the

15 imaging chips 14 are mounted. Two tie bars connect each pair of imaging subarrays. One tie bar is on either side of the imaging chips 14. The tie bars are attached to the same face of the printed wiring boards as are the imaging chips. Because the coefficient of thermal expansion of the glass tie bar is approximately the same as the coefficient of thermal expansion of the imaging

20 chip, the spacing of the imaging elements 18 on the adjacent imaging chips 14 of the two subarrays remains virtually unchanged over a wide temperature range.

An adhesive 28 that is cured by a mechanism other than heat attaches the tie bars 26 to their respective printed wiring board substrate 16.

25 Using a mechanism other than heat to cure the adhesive reduces the possibility of deforming the structure during assembly because of heat induced expansion of the substrate wiring board or other elements. In the preferred implementations, a light curable adhesive, and particularly an ultraviolet light curable adhesive, secures the tie bars 26 to the substrates 16.

An exemplary adhesive is Loctite 352 UV-curable adhesive available from Loctite Corp. of Rocky Hill, CT. A light curable adhesive polymerizes in the presence of high concentration radiant light. A UV curable adhesive polymerizes in the presence of UV light 30 (100-400 nanometer wavelength) from a light source 32. Other light curable adhesives polymerize in the presence of either UV or visible light (100-760 nanometer wavelength).

Referring now to Figures 4 and 5, the edges of the silicon chips 14 are preferably cut in a fashion to facilitate the close placement of the chips relative to one another, and to reduce the possibility of fragmenting the corners of the chip. Referring first to Figure 4, the adjacent edges of the sensor chips may include back cuts 34. These back cuts are open-ended grooves on the backsides of the silicon chips, at the edge of the chip. The back cut 34 counters the tendency of the lower portion of the chip to extend beyond the upper surface. Such lower extensions may tend to interfere with the ability to closely space the sensor chips. Such back cuts are shown, for example, in U.S. Patent No. 4,814,296. In one application in which the sensor chips have a thickness of approximately 17 mils (0.43 mm), the back cuts at the edges thereof provide a thickness of each chip in the area of a back cut of about 6 mils (0.15 mm).

Referring next to Figure 5, an enlarged view of the corner of a chip 14 shows a diagonal cut 36 along the upper edge of each sensor chip. The cut 36 is aligned with the crystalline structure of the chip, reduces the possibility of damage at the corner of the chip. Such diagonal cuts are well known to those familiar with the semiconductor arts, and are also described in U.S. Patent No. 4,814,296. Such cuts are formed by a V shape groove in the upper surface of the silicon wafer at the point at which the wafer is to be divided into individual chips or die. The individual die are separated along the V shaped groove, by sawing or other methods that are conventional in the semiconductor arts.

In a method of forming an imaging apparatus in accordance with an aspect of the present invention, imaging subarrays 12 are formed by securing semiconductor imaging chips 14 to a substrate, such as a printed wiring board 16. The semiconductor imaging chips are secured to the printed wiring board substrate using attachments conventional and well known in the semiconductor arts. The semiconductor imaging chip 14 at the end of the printed wiring board overhangs the end of the board.

Adjacent imaging subarrays 12 are brought proximate one another, with the joining end of one board (with an overhanging chip) adjacent the joining end of the other board (also with an overhanging chip). The projecting end chip of one subarray is positioned immediately adjacent the projecting end chip of the next subarray. The imaging subarrays are aligned so that the imaging elements 18 of the chips are exactly aligned with one another. The end chips of the adjacent subarrays may even be brought into contact with one another.

During the assembly process, the imaging subarrays can be held in place on an assembly supporting structure or jig, such as the aluminum frame 38 shown in Figure 1. Clips 40 hold the printed wiring board 16 of each subarray 12 in place until the tie bars 26 are affixed with the adhesive 28.

Referring particularly to Figure 3, a portion of light curable adhesive 28 is applied to the upper surface of each of the adjacent printed wiring boards 16A, 16B. The glass tie bar 26 is then positioned so that one portion of the tie bar (preferably near one end thereof) contacts the light curable adhesive on the first board 16A, and a second portion of the tie bar (preferably at the other end thereof) contacts the light curable adhesive on the second board 16B. Light 30 is then directed from a light source onto the light curable adhesive 28. In the case of UV curable adhesive, this light should be ultraviolet light, with a wavelength of approximately 375 nm, and wavelength

of between 100 nm and 400 nm. In the illustrated arrangement, light is directed through the tie bar itself, so the glass of the tie bar should be transparent or substantially transparent to light of the wavelength appropriate for curing the adhesive. Light curable adhesives require a light intensity at the adhesive of between approximately 25 mW/cm and 100 mW/cm. The intensity of the light source 32 may need to be adjusted to account for the possibility that the glass tie bar itself may absorb some of the light energy. The specific wavelength and intensity of light required depends on the particular adhesive chosen, and is specified in the adhesive manufacturer's documentation.

As is understood by those familiar with light curable adhesives, the adhesive 28 becomes "tacky" as soon as the adhesive is exposed to light, and is cured within a very short time, such as 5 seconds for a very high intensity light source, and slightly longer for relatively lower intensity sources. Because of the rapid cure time, the probability of relative movement among the parts during the curing process is minimized.

Preferably, the assembly is not moved between when the subarrays are positioned relative to one another and when the adhesive is cured. Moving the assembly may alter the spatial relationships among the imaging chips. Temperature changes during subarray assembly should also be avoided. Temperature induced expansion or contraction of the printed wiring boards, and differential expansion or contraction between the printed wiring boards 16 and the assembly supporting structure 38 may also alter the spatial relationship among the imaging chips. After the tie bars 26 have been affixed to the printed wiring boards, the clips 40 may be unfastened, and the entire imaging assembly can be removed from the assembly supporting structure 38.

